BRITISH STANDARD

BS 4551 :
Part 1 : 1998

# Methods of testing mortars, screeds and plasters

## Part 1. Physical testing

ICS 91.100.10

# Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee B/519, Masonry and associated testing, upon which the following bodies were represented:

Autoclaved Aerated Concrete Products Association
Brick Development Association
British Ceramic Research Ltd.
British Precast Concrete Federation Ltd.
Building Employers' Confederation
Concrete Block Association
Department of the Environment (Building Research Establishment)
District Surveyors' Association
Local Authority Organizations
Mortar Producers Association Limited
National House (Building Council)
Royal Institute of British Architects

The following bodies were also represented in the drafting of the standard, through a subcommittee:

British Aggregate Construction Materials Industries
British Cement Association
British Civil Engineering Test Equipment Manufacturers' Association
British Lime Association
British Vermiculite Association
Cement Admixtures Association
Cementitious Slag Makers' Association
Electricity Association
Institute of Concrete Technology
Quality Ash Association

This British Standard, having been prepared under the direction of the Sector Board for Building and Civil Engineering, was published under the authority of the Standards Board and comes into effect on 15 February 1998



**Amendments issued since publication**

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The following BSI references relate to the work on this standard:
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# Contents

# Foreword

This British Standard has been prepared under the direction of Technical Committee B/519, and is a new edition comprising section **1** and section **3** of BS 4551 : 1980. The main purpose of this new edition is to accommodate the changes brought about by the separating out of chemical methods of test to form BS 4551 : Part 2 and to introduce a small technical amendment to subclauses **10.2.1** and **10.2.3** of the 1980 edition.
BS 4551 : Part 1 : 1998, together with Part 2 : 1998, supersedes BS 4551 : 1980, which is withdrawn.

This edition introduces technical changes, but it does not reflect a full review or revision of the standard which will be undertaken in due course, and which is likely to implement a new European Standard currently under development.

**Compliance with a British Standard does not itself confer immunity from legal obligations.**

**Summary of pages**

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 26, an inside back cover and a back cover.

# Method

## 1 Scope

This Part of BS 4551 specifies methods of sampling, preparation and physical testing of mortars for bricklaying, screeding, plastering and rendering.

The methods given in this standard are not intended to be applied to mortars containing high alumina cement.

## 2 References

### 2.1 Normative references

This Part of BS 4551 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 4551 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

### 2.2 Informative references

This Part of BS 4551 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

## 3 Definitions

For the purposes of this Part of BS 4551, the definitions given in Sections 6.1, 6.2, 6.3 and Subsection 6.6.2 of Part 6 of BS 6100 apply.

## 4 Sampling

### 4.1 Principle

This clause deals with the sampling of mortars and their subsequent reduction on site to a quantity suitable for despatch to a laboratory. It also includes directions for packaging and labelling of the samples.

### 4.2 Freshly mixed mortars

#### 4.2.1 *General*

Samples shall be obtained by taking uniformly distributed increments. The samples shall be immediately combined and mixed thoroughly to form a representative combined bulk or sub-sample. The bulk or sub-sample shall be reduced in accordance with **4.2.4**.

NOTE 1. It is preferable that samples are obtained from material in motion, provided this can be carried out in safety.

NOTE 2. The number of increments and the size of the bulk or sub-sample necessary depends on the quantity of the material and its variability, and the accuracy required of the test results.

#### 4.2.2 *Apparatus*

**4.2.2.1** *Receptacle or scoop*, metal, and of not less than 1 l capacity.

**4.2.2.2** *Airtight containers*. The containers shall be clean and dry at the commencement of the sampling operation.

#### 4.2.3 *Taking of samples*

**4.2.3.1** *Batch mixers*

Sample the mortar at the discharge point of a batch from the mixer. Take not less than 12 increments spaced evenly through the batch. Take the increments by passing the receptacle across the stream of mortar in such a manner as to collect a thoroughly representative sample of mortar.

**4.2.3.2** *Conveyors, pumps, etc.*

Where possible, take increments at the discharge of a conveyor or pipeline. Pass the receptacle across the stream of material, if possible so as to catch the whole of the stream, until it is filled. If it is not possible to catch the whole stream at once, pass the receptacle through the stream at a uniform rate in a manner that is varied on a systematic pattern for successive increments.

Where it is not possible to sample at the discharge point of the conveyor, take increments using a scoop from the full width and thickness of the stream of material on the conveyor after stopping the conveyor. The scoop used shall sweep the surface of the conveyor.

Take not less than 12 increments at regularly spaced intervals during the passage of the whole of the quantity of the material that is being sampled. Combine the increments to form one bulk sample.

**4.2.3.3** *Large hoppers, bins or heaps*

Sample the mortar in accordance with **4.2.3.2** only when hoppers, etc., are being filled, prepared, emptied or removed.

**4.2.3.4** *Small hoppers, bins or heaps*

Sample the mortar by means of the scoop at regular spacings throughout the mass. Take increments from material well below the surface in at least 12 different places in the mass, distributed in a regular manner so as to ensure, when mixed, a thoroughly representative combined sub-sample.

**4.2.3.5** *Bulk transport vehicles*

Either sample the contents of bulk transport containers during filling or emptying by the procedures given in **4.2.3.2** or, when this is not practicable, by taking sub-samples as described in **4.2.3.4**.

#### 4.2.4 *Reduction of sample*

Reduce the bulk sample or sub-sample(s) to a mass of not less than 15 kg by taking sufficient scoopfuls from random positions throughout the mixed material. The reduced sample shall be placed in one or more airtight containers.

NOTE. If the consistence and air content tests are to be made on a sample, arrangements should be made to carry out the tests at the point of sampling.

#### 4.2.5 *Packaging and certificate of sampling*

Each sample to be despatched to a laboratory shall be placed in one or more airtight containers, and suitably labelled so that its origin can be identified at the laboratory. The sample shall be accompanied by a certificate from the person responsible for taking the sample stating that sampling was carried out in accordance with the requirements of this British Standard.

The certificate shall include as much of the following information as is appropriate:

a) type of material;

b) the date, time, place and method of sampling;

c) the quantity of the batch and consignment, or the period of production represented by the sample;

d) tests required.

### 4.3 Hardened mortars

#### 4.3.1 *General*

Because of the variety of circumstances in which sampling of hardened mortars may be required, only general guidance is given here. Samples may be required to ascertain the following:

a) the variability in different parts of the work.

For this purpose, sub-samples should be kept separate and the areas represented by each should be carefully recorded. Results of tests on such samples should be regarded only as representative of the mortar from the area indicated;

b) the composition at specific points, e.g. where defects have been observed.

In this case, the location and the depths from the surface of the work represented by the sample should be recorded;

c) the average composition over a significant area of masonry, plastering, rendering, or screed.

For this purpose, it should be realized that a number of different batches may have been used, and a number of sub-samples of approximately equal mass should be taken from representative areas and combined to make a composite main sample, which is as representative of the average as is practicable. The uncertainties in doing this inevitably limit the value of such average samples and these should be recognized when interpreting results. Care should be taken to avoid taking samples for this purpose predominantly from points at which the mortar is more readily extractable since the mortar at such points is likely to be untypical of the average composition;

d) information about adhesion.

In this case the sample should include the substrate.

#### 4.3.2 *Apparatus*

**4.3.2.1** *Tools for cutting out the sample*, such as hammer and bolster or cold chisel, or masonry or core drill.

**4.3.2.2** *Means of collecting representative samples*, without loss of fine material.

**4.3.2.3** *Containers*, that will prevent sample loss or contamination.

#### 4.3.3 *Size of samples*

Samples for despatch to the laboratory shall each be not less than 100 g in mass. Where a number of sub-samples are combined to form one composite main sample, about the same amount of each sub-sample shall be included.

Where samples are intended to represent averages of the mortar over substantial areas of work, sub-samples shall be combined to form a composite main sample. The minimum size of sub-sample for each 10 $m^2$ and the maximum area represented by each composite main sample shall be as given in table 1.

**Table 1. Representative sample sizes**

| | **Minimum mass of sub-sample to represent 10 $m^2$**<br>g | **Maximum area represented by each composite main sample**<br>$m^2$ |
|---|---|---|
| Brick or block work | 50 | 50 |
| Plastering or rendering | 50 | 50 |
| Floor screed | 100 | 100 |

#### 4.3.4 *Taking of samples and source*

**4.3.4.1** *Masonry mortar*

Take a number of sub-samples sufficient to produce a representative quantity of mortar by removing a number of bricks or blocks from the construction. For most purposes, carefully remove the mortar from the bricks or blocks, avoiding contamination with the material of which they are composed. Take each sub-sample over the thickness of the structure of which it is intended to be representative, and record that thickness.

Where it is essential to avoid the removal of bricks or blocks, take the sub-samples using a masonry drill or core drill, or by chipping away the mortar. Ensure that the sub-samples are not contaminated with the material of which the bricks or blocks are composed, and that there is no loss of the finer material.

**4.3.4.2** *Plastering and rendering mortar*

Take sub-samples from regularly spaced positions over the area to be examined. Where adhesion is good, cut out cores and, for most purposes, remove any adhering background material. Examine the background and record any observations.

NOTE 1. When a failure of adhesion to the background has occurred, appropriate areas may be removed with any convenient tool.

NOTE 2. When adhesion has failed between coats of mortar, separate sub-samples of each coat should be taken.

**4.3.4.3** *Screeding mortar*

Each sub-sample shall be a coherent piece of full depth. Take the sub-samples from regularly spaced positions over the area to be examined. When a failure of adhesion to the sub-base has occurred break out appropriate sub-samples, using a hammer and cold chisel or bolster. Where adhesion is good, cut out or core the sub-samples. Examine the surface of the sub-base for the presence of grout and/or foreign matter.

#### 4.3.5 *Packaging and certificate of sampling*

Each sample to be despatched to a laboratory shall be placed in one or more containers and suitably labelled so that its origin can be identified at the laboratory. The samples shall be accompanied by a certificate from the person responsible for taking the sample stating that sampling was carried out in accordance with the requirements of this British Standard.

The certificate shall include as much of the following information as appropriate.

a) the date, time, place, and method of sampling;

b) the location in the building of the area sampled, and the depths from the face of the structure represented by the sample;

c) the state of the mortar at the time of sampling, e.g. wet or dry, soft or hard;

d) such information as is available on the nature of the contiguous material, e.g. the type of brick or block, and any adhering material such as finishing plaster, paint, grout;

e) reason for investigation and specified mix, if known.

## 5 Laboratory preparation of mortar mixes

### 5.1 Principle

This clause deals with the procedure to be followed when mortar is to be made from stated materials by mixing under laboratory conditions. General laboratory mixes should be made to the mass proportions specified in **5.2.7**. There may, however, be a need for these mix proportions to be modified on the specific occasion when a change of proportions is required in order to obtain certain specified mortar properties.

NOTE. Table 2 may be used as a guide to the quantities of mortar required for the various tests.

### 5.2 Materials and proportioning

#### 5.2.1 *Fine aggregate (sand)*

Any sample of fine aggregate (sand) to be used in mortar tests shall be thoroughly mixed before portions are withdrawn for use. Portions for test shall be taken either by using a suitable sample divider or by taking increments at random from the bulk as described in BS 812. All masses are based on dry fine aggregate (sand), and appropriate adjustments shall be made if damp fine aggregate (sand) is used.

Where standard fine aggregate (sand) is to be used it shall conform to BS 4550 : Part 5, but with the proportions of the various fractions in the mortar as given in table 3 of this standard.

**Table 2. Guide to minimum quantity of material required for various tests**

| Clause number | Test | Volume of mortar to fill mould<br>ml | Number of tests required[1)] | Total volume of mortar<br>ml | Mass of fine aggregate (sand)[2)]<br>g | Remarks |
|---|---|---|---|---|---|---|
| **7** | Consistence, by dropping ball | 200 | 3 | 600 | 1020 | Mortar may be used for other tests |
| **8** | Consistence retentivity and water retentivity | 200 | 2 | 400 | 680 | Mortar is discarded, but this test may be combined with that in clause **7** |
| **9** | Flow | 290 | 2 | 580 | 990 | Mortar is discarded |
| **10.2** | Air content, by density method | 500 | 1 | 500 | 850 | Mortar may be used for the other tests |
| **10.3** | Air content, by pressure method | 500 | 2 | 1000 | 1700 | Mortar is discarded, but this test may be combined with that in **10.2** |
| **11** | Stiffening rate | 550 | 2 | 1100 | 1870 | Mortar not available for other tests |
| **12** | Strength | | | | | Mortar not available for other tests |
| | 25 mm × 25 mm × 160 mm prisms | 63 | 6 | 380 | 640 | |
| | 40 mm × 40 mm × 160 mm prisms | 255 | 6 | 1530 | 2600 | |
| | 70 mm cubes | 355 | 6 | 2130 | 3620 | |
| | 100 mm cubes | 1000 | 6 | 6000 | 10200 | |

NOTE. No allowance has been made for wastage.
[1)] The number of tests required gives the specimens for moulding to give the minimum number of test results.
[2)] Where the mortar is to be made solely for testing, this column applies. The mass of fine aggregate (sand) required for each test is calculated from the total volume of mortar by multiplying this by 1.7, an assumed relative bulk density for the fine aggregate (sand). No allowance therefore has been made for any increase in volume resulting from air entrainment or other causes.

**Table 3. Percentages of fractions of standard fine aggregate (sand)s**

| Fraction | A | B | C | D | E |
|---|---|---|---|---|---|
| Size | 2.36 mm to 1.18 mm | 1.18 mm to 600 μm | 600 μm to 300 μm | 300 μm to 150 μm | 150 μm to 90 μm |
| Percentage | 20 | 20 | 25 | 20 | 15 |

**5.2.2** ***Cement***

Any sample of cement shall be tested in accordance with the requirements of the appropriate standard, i.e. BS 12, BS 4027 or BS 5224, and shall conform to the stated limits.

**5.2.3** ***Lime***

Any sample of hydrated lime shall be tested in accordance with the requirements of BS 890. The available lime content of the sample, and also the free water content of lime putties, shall be determined using a $(1 \pm 0.01)$ g sample according to the methods given in **8.2.3** and **8.2.2** of BS 4551 : Part 2 : 1998.

**5.2.4** ***Gypsum***

All samples of gypsum plaster shall be thoroughly mixed to render homogeneous before portions are withdrawn for use. The sulfate content shall be determined by the method given in BS 1191. Report as $CaSO_4.½H_2O$.

**5.2.5** ***Ready-mixed lime: fine aggregate (sand) for mortar***

Any sample of ready-mixed lime: fine aggregate (sand) for mortar shall be tested in accordance with the requirements of this standard and conform to the stated limits (see **10.2** of BS 4551 : Part 2 : 1998).

#### 5.2.6 *Air-entraining agent*

Any sample of air-entraining agent shall be tested in accordance with the requirements of BS 4887 : Part 1 and shall conform to the stated limits.

#### 5.2.7 *Batch proportioning of mixes*

All batching shall be by mass. Table 4 gives ranges of composition for mixes using fine aggregate (sand)s with a range of gradings.

For laboratory prepared mixes, except where particular properties of the mortar are specified, the proportions by mass shall be used as given in table 4.

NOTE. Although the properties of these mixes may differ slightly from those prepared using proportions based on actual bulk density values, this procedure is adopted in the interests of standardization.

**Table 4. Composition of laboratory mixes**

**Cement : fine aggregate (sand) screeds**

| Screed designation | Percentage by mass on dry mass screeds % | Traditional volume proportioning |
|---|---|---|
| | Portland cement | cement : fine aggregate (sand) |
| a | 22.8 | 1 : 3 |
| b | 18.0 | 1 : 4 |
| c | 14.0 | 1 : 5 |

**Cement-based mortars and plasters**

| Mortar designation | Percentage by mass on dry mass of mix % | | | | | | |
|---|---|---|---|---|---|---|---|
| | cement : | fine aggregate (sand) | cement : | lime : | fine aggregate (sand) | masonry cement : | fine aggregate (sand) |
| i | 22.8 | 77.2 | 22.9 | 1.5 | 75.6 | — | — |
| ii | 20.5 | 79.5 | 17.0 | 3.1 | 79.9 | 22.3 | 77.7 |
| iii | 14.0 | 86.0 | 13.6 | 5.1 | 81.3 | 15.8 | 84.2 |
| iv | 10.5 | 89.5 | 9.0 | 6.4 | 84.6 | 12.8 | 87.2 |
| v | 9.8 | 90.2 | 7.1 | 8.0 | 84.9 | 11.0 | 89.0 |

**Gypsum : lime : fine aggregate (sand) plasters**

| Traditional volume proportioning | | | Percentage by mass on dry mass of mix % | | |
|---|---|---|---|---|---|
| gypsum : | lime : | fine aggregate (sand) | gypsum (as $CaSO_4.½H_2O$) | lime ($Ca(OH)_2$) | fine aggregate (sand) |
| 1 | 0 | 1.5 | 18.0 | — | 82.0 |
| 3 | 2 | 6 | 13.5 | 8.5 | 78.0 |
| 1 | 1 | 3 | 9.5 | 9.0 | 81.5 |
| 1 | 3 | 9 | 3.5 | 10.0 | 86.5 |

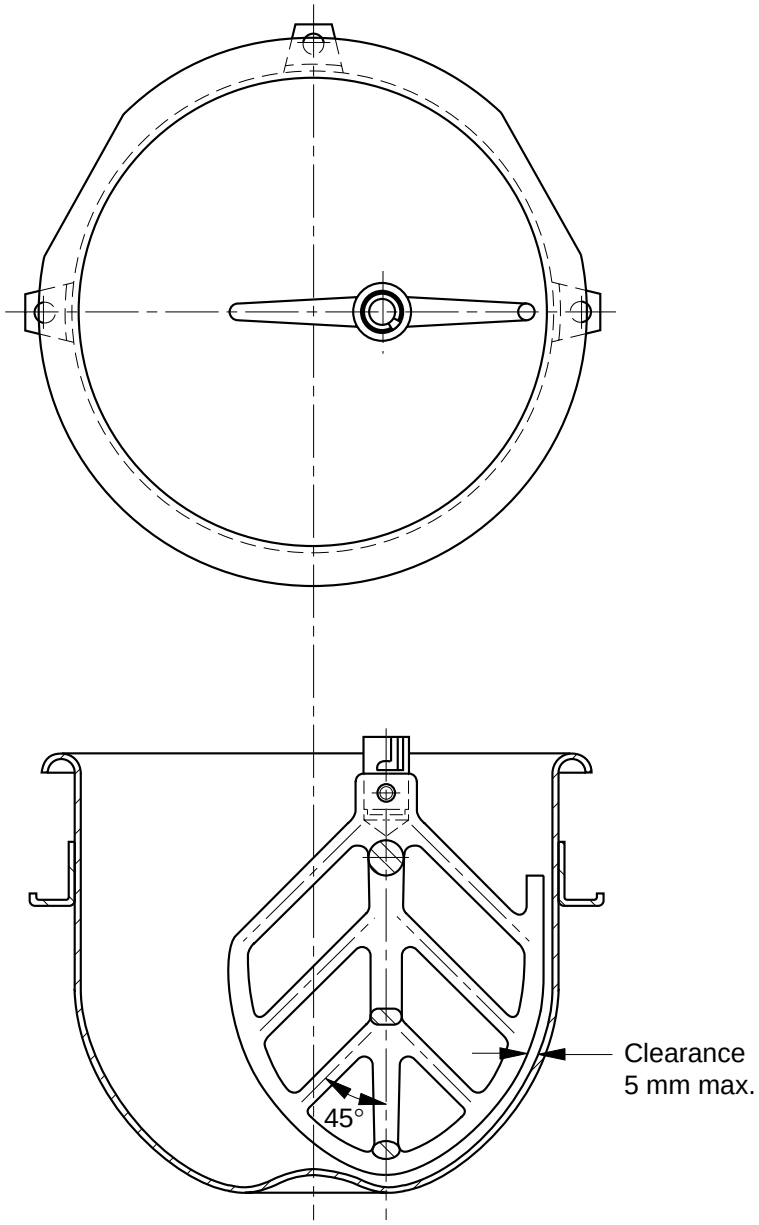



**Figure 1. Typical mixer bowl and blade**

### 5.3 Mixing apparatus

**5.3.1** *Mixer*, with a blade rotating axially at (120 ± 25) r/min and in a planetary motion at (60 ± 15) r/min, with a bowl and blade of the general form shown in figure 1, and a capacity of between 5 l and 20 l according to the amount of mortar required by the testing laboratory.

### 5.4 Mixing procedures

**5.4.1** ***When solid ingredients are to be mixed with liquids***

Bring all the materials to a temperature of (20 ± 2) °C before commencing the mixing of the mortar. Carry out the mixing in a room temperature of (20 ± 5) °C but preferably within closer limits.

Place all the solid materials in the mixing bowl of the appropriate size and mix for 30 s.

NOTE. When a powdered admixture is used, and if this has not been dissolved in the mixing water, it will be necessary to premix it with one of the dry materials for several minutes to ensure adequate dispersion.

Over the next 30 s, and while mixing, pour the water plus any admixtures already mixed or dissolved, at a uniform rate into the bowl. Continue mixing for 60 s after all the liquid necessary to achieve the required consistence has been added.

Stop the mixer and clean any adhering material from the paddle and sides in about 15 s with a scraper. Take particular care to ensure no unmixed materials remain at the bottom of the bowl. Cover the bowl with a damp cloth and allow the mortar to stand for a total of 10 min.

Restart the mixer and mix the mortar for a further 60 s.

**5.4.2** ***When using lime putty***

Premix the fine aggregate (sand) and lime in the mixer until the lime appears to be uniformly distributed before continuing as described in **5.4.1** above.

**5.4.3** ***Cement : fine aggregate (sand) screeding mortar***

The dropping ball consistence measurement is inappropriate for control of this type of material, which has a consistence value below that which is measurable by dropping ball, hence the mixes shall have a total water : cement ratio of 0.5 for 1 : 3, 0.55 for 1 : 4 and 0.65 for 1 : 5.

**5.4.4** ***Period between mixing and testing***

Samples of mortar shall be tested as soon as practicable after mixing has been completed, as the properties of all mortars change in some degree with time; the period between completion of mixing and the beginning of any test on the mix shall be reported. Cement-based mortars, plasters and screeds, unless specially retarded, shall be tested within 30 min of mixing and gypsum : lime : fine aggregate (sand) plasters using commercially retarded browning plaster shall be tested within 30 min of mixing.

## 6 Procedure for plant and site mixed mortars

### 6.1 Principle

This clause describes the procedure to be followed when the mortar is submitted to the laboratory in a ready-mixed form.

### 6.2 Examination of samples

Samples of mortar received at the laboratory for test shall be examined to ascertain whether leakage, evaporation, segregation or bleeding of liquid has occurred in transit. The whole of the sample, with any liquid that has separated or condensed on the inside of the container, shall be removed completely and mixed without loss of water to render it homogeneous.

Where possible, the temperature of the material shall be adjusted to $(20 \pm 5)$ °C, without loss of water but, if this is not practicable, the temperature of the material at the time of test should be noted.

### 6.3 Period between mixing and testing

Retarded cement-based mortars, plasters and screeds shall be tested not more than 4 h after manufacture.

NOTE. Ready-mixed lime : fine aggregate (sand) for mortar may be tested, when not gauged with Portland cement or gypsum, at any time after manufacture.

### 6.4 Ready-mixed lime : fine aggregate (sand) for mortar

When ready-mixed lime : fine aggregate (sand) for mortar is to be tested after the addition of cement or gypsum the following procedure shall be adopted.

Place the mixture in a mixer as specified in **5.3** and mix for 30 s. Over the next 30 s, and while mixing, add the cement or gypsum at a uniform rate into the bowl. Continue mixing for 30 s after all the binder has been added.

Over the next 30 s, and while mixing, pour the water plus any admixtures already mixed or dissolved, at a uniform rate into the bowl. Continue mixing for 60 s after all the liquid necessary to achieve the required consistence, has been added.

Stop the mixer and clean any adhering material from the paddle and sides in about 15 s with a scraper. Take particular care that no unmixed materials remain at the bottom of the bowl. Cover the bowl with a damp cloth and allow the mortar to stand for a total of 10 min. Restart the mixer and mix the mortar for a further 60 s.

## 7 Determination of consistence by dropping ball

### 7.1 Principle

This clause specifies the procedure to be used for the determination of the consistence of the mortar by the dropping ball test.

### 7.2 General

When testing site made materials, the dropping ball penetration shall be determined at the point of sampling and reported (see **4.2.4** note). For certain tests on mortar mixes prepared in the laboratory, the consistence shall be adjusted to a penetration of $(10 \pm 0.5)$ mm (but see **5.4.3**).

Preliminary tests in accordance with this clause are therefore required in order to determine the appropriate water content.

### 7.3 Apparatus

**7.3.1** *Mould made from a rigid material*, 100 mm internal diameter, 25 mm internal depth.

**7.3.2** *Palette knife.*

**7.3.3** *Methyl methacrylate ball*, having a diameter of $(25 \pm 0.1)$ mm, and a mass of $(9.8 \pm 0.25)$ g with its surface polished all over.

**7.3.4** *Dropping mechanism* for the ball, that does not impart to the ball any appreciable spin, friction or acceleration, other than that due to gravity, in the process of release, and ensures that the ball falls freely and drops vertically within the limits specified in **7.4**. A suitable apparatus is shown in figure 2.

**7.3.5** *Device for measuring the depth of penetration of the ball*, in millimetres, with an accuracy of 0.1 mm, without imposing any pressure on the ball in the process of measurement. The device shall also be suitable for measuring any fall in the level of the surface of the mortar in the test for consistence retentivity (see clause **8**). A suitable measuring device is shown in figure 3.

NOTE. In both tests the mortar is initially trowelled flat and level with the top of the mould, and this level is used as the datum for measurement. Instruments with a tripod stand that rests on the rim of the mould are therefore suitable. Such tripod stands should allow for sufficient sliding movement to permit measurement of the penetration of a ball in any position within the 12 mm from the centre of the surface that is allowed in **7.4**.

The requirement that no pressure shall be imposed on the ball in the process of measurement is most easily satisfied by a device that incorporates a measuring foot, having a horizontal base of sufficient width to ensure that measurements are made on the highest point of the ball, and that can be brought slowly down on the ball whilst sighting across the top of the ball. A white sight screen behind the ball helps to determine when the measuring foot just touches the ball.

**7.4 Procedure**

Fill the mould with the mortar, in about 10 increments, by pushing the mortar into it with the end of a palette knife. When the mortar is slightly above the rim of the mould, strike off the surface plane and level with the top of the mould, using the palette knife. Hold the knife at about 45° and move once across the mould with a sawing motion to strike off excess material, and then at a slightly flatter angle to trowel the surface in a single action in the reverse direction.

NOTE. The surface should not be trowelled further unless the consistence of the mortar is so low that the two movements are insufficient to produce the required finish.

Allow the methyl methacrylate ball to fall freely through a height of 250 mm before striking the surface of the mortar to land within 12 mm of the centre of the surface. Measure the penetration of the ball and record to the nearest 0.1 mm. Remove the ball from the mortar, rinse, wipe with a clean cloth and replace in the release mechanism. Except where the mortar is to be used for the consistence retentivity or water retentivity tests, return the mortar to the mixing bowl.

Make three tests on separate portions of the mortar. Report the average of the three penetrations to the nearest 0.1 mm as the consistence.

NOTE. The tests for consistence retentivity and water retentivity may be done in conjunction with this test on the same specimen.

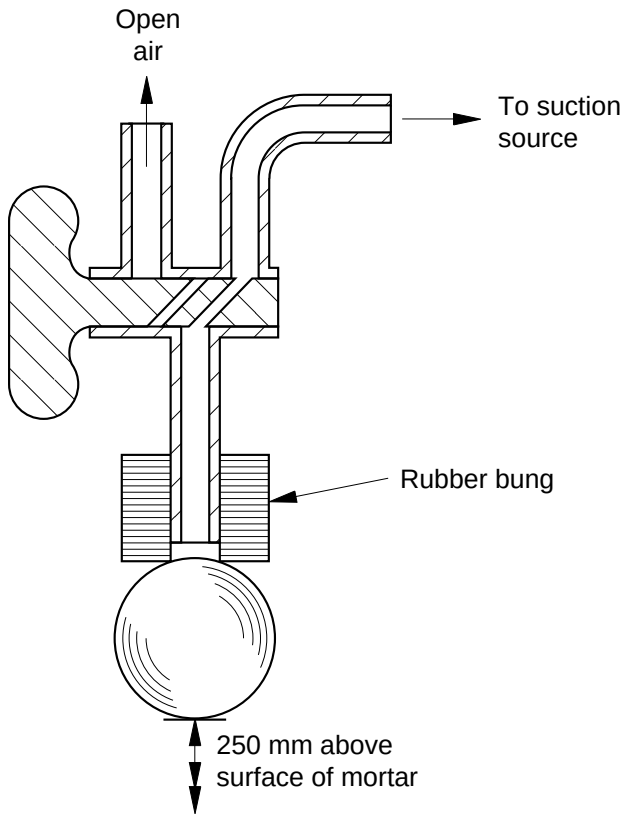



**Figure 2. Diagrammatic representation of ball release**

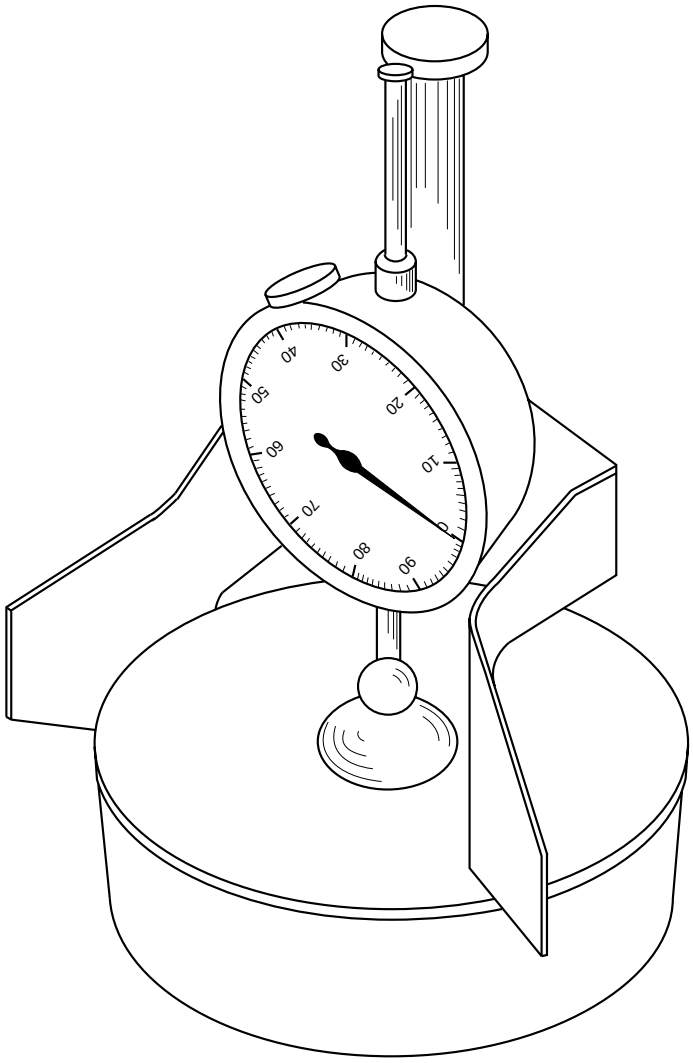



**Figure 3. Suitable device for measuring penetration**

## 8 Determination of consistence retentivity and water retentivity

### 8.1 Principle

The retention of consistence and of water in mortars is of considerable practical importance, particularly if the mortar is to be applied on materials of high suction. Since the consistence of a given mortar is dependent upon both water content and entrained air content, it is not sufficient with all mortars to measure the water retained under a standard test condition, and the degree to which the mortar retains its consistence is the more useful measure for general use.

Accordingly, this clause deals with two tests to determine properties of the mortar before and after applying a standard suction treatment to the mortar.

In one test the consistence is measured, and the final consistence value, expressed as a percentage of the original value, is termed the 'consistence retentivity'. In the other test, the mass of the water retained after suction is measured and, when expressed as a percentage of the original water content, is termed the 'water retentivity'; it is of value in comparing mortars of closely similar type.

### 8.2 Apparatus

**8.2.1** *Mould made from a rigid material*, as described in **7.3.1**.

**8.2.2** *Palette knife.*

**8.2.3** *A 2 kg weight.*

**8.2.4** *Rigid non-porous plate*, 110 mm in diameter.

**8.2.5** *Two discs or two squares of white cotton gauze.* The discs shall be 110 mm in diameter and the squares shall be of side 100 mm.

**8.2.6** *Eight discs of extra white filter paper*, 200 g/m$^2$, 110 mm in diameter.

### 8.3 Procedure

NOTE. These tests may be done in conjunction with the dropping ball method for measuring consistence (see clause **7**). Both consistence and water retentivity measurements can be made on the same filling of the mould.

The mortar used shall be discarded after completion of the consistence retentivity and water retentivity tests.

Weigh the mould in a dry condition and weigh eight discs of filter paper. Fill the mould with mortar and strike off the surface plane and level in two movements, as described in **7.4**. Remove all the mortar from the outside of the mould and determine the consistence of the mortar by the dropping ball test as described in **7.4**. Fill the depression left by the ball with mortar and strike off plane and level in two movements. Weigh the mould and its contents.

Cover the surface of the mortar with two pieces of cotton gauze, and place eight discs of filter paper on top of the gauze. Place the non-porous plate on top of the filter papers and load with the 2 kg mass. After 2 min, remove the mass, discard the cotton gauze and weigh the filter papers to the nearest 0.05 g.

NOTE. Alternatively, the mass of the full mould may be used to determine the water removed, in which case it is unnecessary to first weigh the filter paper.

Calculate the mass of water originally present in the mould from the mass of mortar in the mould and the moisture content of the mortar. Where the moisture content is not known from the composition of the mortar, it shall be determined at the same time on a fresh sample of the mortar by the method described in **8.2.2** of BS 4551 : Part 2 : 1998. The mass of water retained by the mortar after suction, i.e. the mass of water originally present in the mould minus the mass of water absorbed by the filter paper, expressed as a percentage of the mass of water originally present in the mould full of mortar, shall be taken as the water retentivity.

Measure any fall in level of the mortar after suction. Make a single measurement of consistence by the dropping ball test on the mortar after suction. Correct the apparent penetration of the ball by subtracting from it any measured fall in the level of the mortar. The corrected penetration of the ball after suction, expressed as a percentage of the average penetration before suction, shall be calculated as the consistence retentivity.

Repeat this procedure with a second sample of mortar, and report the average of the two water retentivity values to the nearest 1 % and the average of the two consistence retentivity values to the nearest 5 %.

## 9 Determination of flow

### 9.1 Principle

This clause describes the procedure to be used for determining the flow of mortars. Since the more plastic and workable mortars are more cohesive, their flow at given consistence is less than that of mortars of lower cohesion. The flow of the mortar is measured immediately after the test for consistence of the mortar (see clause **7**).

The test may be made on a site sample and used to determine the flow of a mortar at the consistence at which it is being used.

Alternatively, a laboratory procedure may be adopted whereby the flow is determined at both a high and low consistence value, and the linear interpolation used to report the value at 10 mm consistence. This more precise method is the one that will generally be used because the method for site samples is limited to a comparison of mortar used on one particular site. Where it is desired to compare different mortars, they should be so compared on a standard consistence value.

### 9.2 Apparatus

**9.2.1** *Flow table*, as described in **A.1**.

**9.2.2** *Mould*, as described in **A.2**.

**9.2.3** *Tamper*, as described in **A.3**.

### 9.3 Procedure

#### 9.3.1 *General*

The measurement of the flow of the mortar shall be carried out immediately after the test for consistence of the mortar. If the table has not been used for 24 h or more, operate for 10 revolutions before use.

Wipe the flow table top until clean and dry, and place the clean, dry mould at the centre. Place a layer of mortar about 25 mm in thickness in the mould and tamp 20 times with the tamper. The tamping shall be just sufficient to ensure uniform filling of the mould.

Fill the mould with mortar and tamp as before. Strike off the mortar surface plane and level with the top of the mould using a palette knife, as described in **7.4**.

Wipe the table top clean and dry, being especially careful to remove any water from around the edge of the mould. Lift the mould away vertically and immediately operate the table 25 times in 15 s. The flow is the resulting increase in average diameter of the mortar, measured on four diameters at equal intervals, expressed as a percentage of the internal base diameter of the mould, and reported to the nearest 5 %.

The mortar shall be discarded after completion of this test.

#### 9.3.2 *Site samples*

Determine the consistence immediately, in triplicate, as described in **7.4**, on a sample taken from a mixer, spot-board, skip etc., (see clause **4**), and then determine the flow as described in **9.3.1**.

#### 9.3.3 *Laboratory samples*

Make three determinations in accordance with **9.3.1** at a consistence of $(9.7 \pm 0.2)$ mm, and three at $(10.3 \pm 0.2)$ mm. Use linear interpolation to report the flow value at a consistence of 10.0 mm.

## 10 Determination of air content of freshly mixed mortars

### 10.1 Principle

This clause deals with two methods of determining the air content of mortars; the density method and the pressure method. For the density method, the relative densities of the constituents and the mix proportions by mass (including the water content) need to be known. None of these data are required for the pressure method but, for this method, special apparatus is necessary.

The report of air content should state which method has been used and, if the density method is used, the values of the densities of the materials used in the calculation should be stated and whether they have been measured or assumed.

### 10.2 Density method

#### 10.2.1 *Apparatus*

**10.2.1.1** *Rigid, thick walled cylindrical container*, of about 0.5 l capacity, with an internal diameter of about 75 mm. The internal surfaces shall be smooth.

NOTE 1. The bowl described in **10.3.1.1** is suitable for this test.

NOTE 2. For ease of cleaning, the joint between the bottom and the walls should have a slight radius.

**10.2.1.2** *Glass plate*, of sufficient size to cover the container.

**10.2.1.3** *Cylindrical tamper*, $(37.5 \pm 0.5)$ mm in diameter, weighing about 250 g and made of hard plastics. The tamping face shall be flat and at right angles to the length of the tamper.

**10.2.1.4** *Balance*, of sufficient capacity and accurate to 0.5 g.

**10.2.1.5** *Metal straightedge*, of suitable length to strike off the surface of the mortar in the container.

#### 10.2.2 *Calibration of container*

Weigh, to ± 0.1 g, the container and the glass plate cover in a clean and dry condition. Fill the container with distilled water at the mixing room temperature. Slide the glass plate cover over the top of the container, making certain that no air bubbles are trapped under the glass plate. Wipe dry the exposed surfaces of the container and the glass plate, and weigh to ± 0.1 g. By removing the glass plate and topping up the container with more distilled water and proceeding as before, make two additional weighings of the container filled with water. Calculate the average mass of water in the full container, and determine the capacity of the container to the nearest 0.1 ml, taking the relative density of water as 1.00.

#### 10.2.3 *Procedure*

Weigh, to ± 0.1 g, the clean and dry container. Fill the container with mortar in four layers each about 25 mm deep. After the addition of the first increment, tamp the surface gently 20 times with the tamper. Distribute the strokes evenly, over the surface only, to give an essentially flat surface. Then place further layers and tamp each in turn in the same way.

Adjust the final layer so that the excess to be struck off is small. With the straightedge held almost vertically, strike off the surface plane and level with the top of the container with a sawing action, making one pass in each of two directions at right angles. Clean and dry the outside of the filled container and weigh to ± 0.1 g.

#### 10.2.4 *Calculations*

The relative density, $D$, of the mortar shall be calculated from the mass of mortar in the measure and the capacity of the measure.

The air content, $A$, as a percentage of the volume of mortar, shall be calculated to the nearest 0.1 % using the following formula:

$$A = 100(1 - KD)$$

where

$D$ is the relative density of the mortar;

$$K = \frac{\left[\frac{M_1}{d_1} + \frac{M_2}{d_2} + \ldots M_w\right]}{M_1 + M_2 + \ldots M_W}$$

and

$M_1$, $M_2$,… etc. are the relative masses of the constituents of the mortar, of relative densities $d_1$, $d_2$… etc.; and

$M_w$ is the relative mass of water present.

Where possible, the relative density of the fine aggregate (sand) used in the mortar shall be determined in accordance with the methods for determination of specific gravity of fine aggregate (fine aggregate (sand)) described in BS 812, and the relative densities of powders, e.g. cements and limes, shall be determined in the usual manner by displacement of liquid in a density bottle. The liquid used shall be redistilled kerosene (paraffin oil). The bottle containing the weighed powder shall be half filled with kerosene and evacuated for at least half an hour on a water pump or vacuum pump before the bottle is filled with kerosene and transferred to a thermostat. The accuracy of determination of the relative density of the powder shall be ± 0.02. For this purpose, the liquid used shall not change in relative density by more than 0.0005 when evacuated for a period of 5 h.

NOTE. A suitable liquid can be prepared in the laboratory by redistilling kerosene and collecting the fraction condensing at 200 °C to 240 °C. Alternatively, petroleum fractions with boiling ranges within the range 190 °C to 255 °C and with sufficiently stable density characteristics are commercially available.

If the relative densities of the materials used in the mortar under examination cannot be determined, the values given in table 5 shall be used.

**Table 5. Relative densities of materials used in mortar**

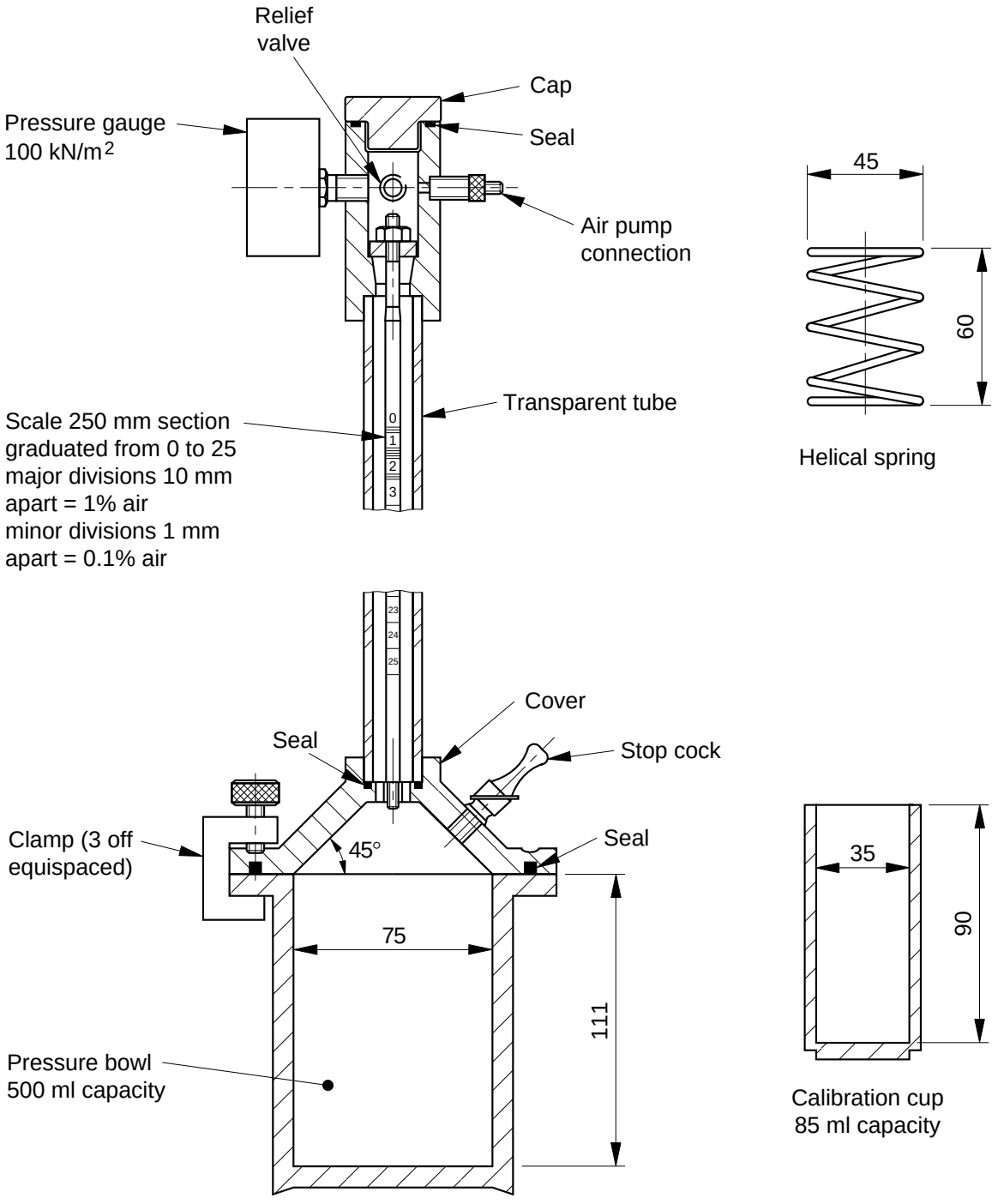
| Material | Relative density |
|---|---|
| Portland cement | 3.12 |
| Masonry cement | 3.05 |
| Silica fine aggregate (sand) | 2.65 |
| White hydrated building lime | 2.26 |
| Grey hydrated building lime | 2.45 |
| Gypsum plaster | 2.32 |

### 10.3 Pressure method

#### 10.3.1 *Apparatus*

**10.3.1.1** *Apparatus for the measurement of air content*, shall be as shown in figure 4. It shall consist essentially of a metal bowl, fitted with a metal cover to which is attached a gauge glass for measurement of volume changes, and a pressure gauge for measurement of the applied air pressure. The gauge shall have low backlash and friction and shall give the same readings within 1.0 kN/m$^2$ on increasing and decreasing pressures when the calibration of the gauge is periodically checked as specified in **10.3.2**.

A change of air content of 0.1 % is indicated with the calibration cup if the air pressure changes by about 0.5 kN/m$^2$. The pressure is applied by a hand pump or compressed air line through the valve. A stop cock is fitted in the cover to allow water to escape when adjusting the water level in the gauge glass.




All dimensions are in millimetres.

**Figure 4. Apparatus for measurement of air content (pressure method)**

A cup shall be provided for calibration purposes as indicated below, and a spring for holding down this cup. A glass plate of sufficient size to cover the bowl shall be provided.

A piece of wire about 0.6 mm in diameter, suitably bent to provide a level support for the calibration cup, shall be placed at the bottom of the bowl.

**10.3.1.2** *Mallet.*

**10.3.1.3** *Trowel.*

**10.3.1.4** *Circle of filter paper*, 70 mm in diameter.

**10.3.1.5** *Glass tube*, with an outside diameter less than 10 mm, fitted with a funnel.

**10.3.2** ***Calibration of apparatus***

Weigh the bowl and the glass plate in a dry condition. Fill the bowl with distilled water at room temperature and determine the temperature of the water. Place the glass plate over the top, making certain that no air bubbles are trapped under the plate. Wipe dry the outside of the bowl and the exposed surfaces of the plate. Weigh the bowl, full of water, with the glass plate in position. This shall be repeated to make a total of three measurements, the average mass and temperature being taken. Calculate the capacity of the bowl using standard tables of the density of water at different temperatures.

The same procedure shall be followed to determine the capacity of the calibration cup. The capacity of the calibration cup as a percentage of that of the bowl shall be calculated.

Place the calibration cup on the wire at the bottom of the bowl with the open end downwards. Place the spring on top of the cup and clamp the head assembly securely in place on the bowl.

NOTE. The wire provides space for water to enter the cup as the air in the cup is compressed.

Slowly introduce water into the head unit assembly to the zero mark on the scale of the glass tube, trapping air in the calibration cup. Apply a small pressure, 20 kN/m$^2$ to 30 kN/m$^2$, to compress the air into the calibration cup and to seal the opening with water. Tilt the bowl at an angle of 45°, revolve, and tap with the mallet several times to remove any air trapped on the inner surfaces. Release the pressure, bring the water again to the zero mark, and then slowly increase the air pressure until the ratio of the volume of the calibration cup to the volume of the bowl, expressed as a percentage, is indicated on the gauge glass. Record the reading on the pressure gauge. Increase the air pressure further by a small amount and then slowly reduce until the original percentage is again indicated on the gauge glass. The reading on the pressure gauge shall again be recorded. Check any difference between the two readings against the limits specified in **10.3.1.1** and, if acceptable, the mean of the two pressures determined in this manner shall be taken as the 'working pressure' which shall be used with the instrument in subsequent tests for air content of mortars. Calibration of the instrument shall be checked periodically to eliminate the possibility of errors due to changes in the pressure gauge.

**10.3.3** ***Procedure***

NOTE. The same sample of mortar can be used for determining the air content first by the relative density method and then by the pressure method. If the relative density method is used, the bowl will have to be wiped and weighed before the pressure test.

Fill the bowl with mortar as described in **10.2.3**. Moisten the filter paper and place on the surface of the mortar, clamping the head unit into position. Lower the small diameter glass tube through the gauge glass until the end is just above the filter paper. Pour water slowly down this tube, and slowly withdraw the tube until the water is up to the zero mark in the gauge glass. Remove the small tube and tilt and rotate the entire assembly while tapping with the mallet to remove air bubbles adhering to the inner surfaces. Bring the water to the zero mark and close the opening at the top with the cap. Apply pressure slightly greater than that determined in the calibration test.

Tap the bowl again with the mallet and bring back the pressure to the working pressure. Immediately read the air content from the gauge glass to the nearest 0.1 %. Reduce the pressure slightly and then slowly increase to the working pressure. Read the air content again to the nearest 0.1 %. Remove the cap from the opening at the top, thereby releasing the air pressure, and the water level should then have returned to the zero mark, within 0.1 %. If this is not so, the test shall be considered invalid. The apparatus shall be checked for leakage, corrected if necessary and a fresh test carried out. Any repeat of the test shall be made on a fresh sample of mortar. The value of air content of the mortar shall be taken as the average of two readings observed at the working pressure.

The mortar shall be discarded after completion of this test.

## 11 Determination of stiffening rate

### 11.1 Principle

The rate at which mortar stiffens on a building site will depend on many factors including water, cement and lime contents, water retentivity, suction rate of contiguous materials, temperature and humidity.

Thus the two methods described in this clause can be used only for tests under controlled laboratory conditions, using on site mixed or laboratory prepared mortars.

### 11.2 General

The stiffening rate for mortar shall be determined in the following manner, either

a) by determining the time after mixing that gives a specified resistance (1.0 N/mm$^2$, 1.5 N/mm$^2$ or 2.0 N/mm$^2$) to penetration by a metal rod of 30 mm$^2$ cross-sectional area; or

b) by comparing the time that gives an agreed resistance to penetration with that of a control mix.

For the second test, the constituent materials of the control mix shall be brought to the temperature of the sample of mortar before starting the test. The tests on the sample and control shall be carried out at the same time, the specimens having been stored under the same conditions, to minimize the effects of variations in temperature and humidity.

### 11.3 Apparatus

**11.3.1** *A dial type platform scale*, preferably with a tare device, reading to at least 15 kg with graduations not greater than 100 g.

**11.3.2** *Disposable rigid open topped moulds (or containers)* for the mortar, at least 75 mm in diameter and 50 mm to 100 mm high.

**11.3.3** *Stop clock.*

**11.3.4** *Brass rod*, 65 mm long and (6.175 ± 0.025) mm in diameter, with one end flat and perpendicular to the axis. At a distance of (25 ± 0.25) mm from this end, the diameter is reduced to 5 mm for the remaining 40 mm. A loosely fitting brass washer, 20 mm in external diameter, rests on the stop formed at the change in diameter of the rod. The rod is held vertically with the 6.175 mm diameter portion downwards, in a device such as a lever type drill stand that enables it to be lowered vertically in a controlled and steady manner over a distance of at least 40 mm.

### 11.4 Procedure

#### 11.4.1 *Laboratory prepared samples*

Measure the time of stiffening from the completion of the mixing of either water to a dry mix, or cement or gypsum to a wet mix of lime and fine aggregate (sand). Mix the mortar by the procedure described in clause **7** of BS 4551 : Part 2 : 1998 and bring to a standard consistence of (10 ± 0.5) mm as determined by the dropping ball test (see clause **7** of this Part of BS 4551).

#### 11.4.2 *Site mixed materials*

The time of stiffening shall be measured from the start of site mixing. On arrival at the laboratory, the consistence shall be determined by the dropping ball test (see clause **7**) and recorded.

#### 11.4.3 *Control mix*

A standard fine aggregate (sand) shall be prepared in the proportions given in table 3. A cement : fine aggregate (sand) control mix containing 20 % by mass of the same cement, or 12.5 % by mass of the same gypsum plaster as used in the sample shall be prepared by the procedure described in clause **5** and shall brought to the same consistence as the sample (see clause **7**).

#### 11.4.4 *Filling of moulds*

Sufficient moulds shall be filled with each mortar for test to provide sufficient area of surface for the required number of penetrations of the rod. Fill each mould with the mortar in about 10 increments, tapping the mould on the bench four times after each increment. Fill the mould so that the excess to be struck off is small. Strike off the surface plane and level with the top of the mould using a palette knife (see **7.4**). The filling of the moulds shall be completed not sooner than 15 min and not later than 20 min after water has been added to the mortar mix.

#### 11.4.5 *Storage of specimens*

The filled moulds shall be stored in air at a temperature of (20 ± 2) °C and a relative humidity of not less than 90 %.

#### 11.4.6 *Resistance to penetration*

Place a mould on the scale under the penetration rod so that the portion of the sample surface immediately beneath the rod is at least 20 mm from the rim of the mould or from the position of any previous penetration. Adjust the tare device or record the mass of the filled mould. By means of the lever on the drill stand, lower the penetration rod slowly into the sample until the loose washer just touches the surface, see figure 5.

Note the reading of the scale in kilograms. This reading, corrected if necessary for the mass of the filled mould, is then divided by 3 to express the resistance to penetration in newtons per square millimetre. For the purpose of this test it is sufficiently accurate to assume that a reading of 1 kg indicates a force of 10 N.

The required resistance to penetration, i.e. 1.0 N/mm$^2$, 1.5 N/mm$^2$ or 2.0 N/mm$^2$ shall be selected and the actual resistance to penetration shall be measured after 2 h, then at intervals of 1 h until the value exceeds half the required resistance and thereafter at 30 min intervals until it exceeds the required resistance.

The mortar shall be discarded after completion of this test.

#### 11.4.7 *Results*

Either:

a) determine the time to give the required resistance to penetration by interpolation of the results immediately below and above this figure; or

b) determine the ratio of the time for the test sample to that of the control sample to give the required resistance to penetration.

Make and test a repeat batch of the same type of mortar. Report the average of the two results to the nearest 15 min for the results in a) or the ratio reported to the nearest 0.05 for the results in b).

## 12 Determination of strength

### 12.1 Principle

This clause gives the procedure for determining the flexural and compressive strength on 25 mm × 25 mm × 100 mm prisms or 40 mm × 40 mm × 160 mm prisms, and compressive strength on 70.7 mm and 100 mm cubes.

Two types of curing are specified:

a) hydraulic curing for mortars that derive their strength mainly from hydration of cement;

b) moist air curing, without carbonation, for gypsum-based or retarded mortars.

Preferred ages of testing cement-based mortars are 7 days and 28 days, the ages being taken from the time of addition of the water to the other ingredients of the mortar. For retarded mortar mixes, the retardation period should be added to the curing time.

Gypsum-based materials are tested after setting and drying in accordance with the requirements of BS 1191.

### 12.2 Preparation of test specimens

#### 12.2.1 *Apparatus*

**12.2.1.1** *Single or gang moulds for prisms* to produce specimens 25 mm × 25 mm in cross section and 100 mm long, or 40 mm × 40 mm in cross section and 160 mm long.

**12.2.1.2** *Compacting bar for prisms*, having a ramming face 12 mm square and a mass of 50 g.

**12.2.1.3** *Palette knife for prisms*, having a straight edge long enough to span the mould.

**12.2.1.4** *Single or gang mould for cubes*, to produce 70.7 mm or 100 mm cubes.

**12.2.1.5** *Compacting bar* for cubes, having a ramming face 25 mm square and a mass of 1.8 kg.

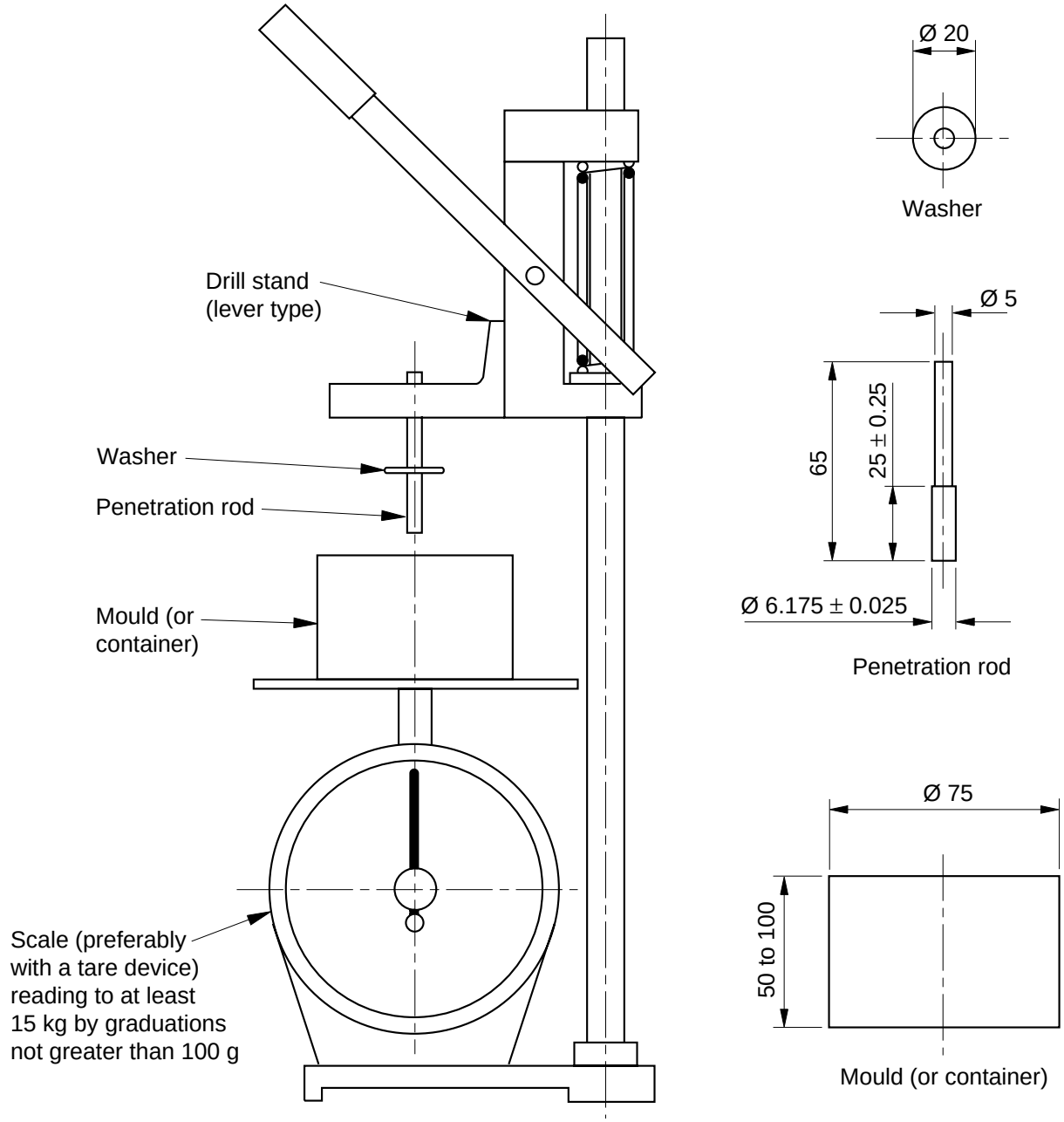
**12.2.1.6** *Palette knife for cubes*, having a straight edge long enough to span the mould.

#### 12.2.2 *Construction of moulds*

The moulds shall be rigid enough to prevent distortion. The surface hardness of each internal face shall be at least 95 Rockwell (scale B) hardness value as described in Part 1 of BS EN 10109[1)]. They shall be constructed in such a manner as to facilitate the removal of the moulded specimens without damage. The parts of the mould, when assembled, shall be positively and rigidly held together and suitable means of ensuring this, both during the filling and the subsequent handling of the filled mould, shall be provided.

Each mould shall be provided with a rigid base plate firmly attached to the mould to give a watertight joint with the sides of the mould when greased.

[1)] The purchaser should note the need to accept the indentations on the faces of new moulds resulting from the hardness test.




All dimensions are in millimetres.

**Figure 5. Determination of stiffening rate of mortar**

#### 12.2.3 *Dimensions and tolerances*

The moulds shall be so made that, when assembled ready for use, the dimensions and internal faces are accurate within the following limits. The principles laid down in BS 308 : Part 3 shall be followed for flatness and squareness and those in BS 1134 : Part 1 for surface texture.

a) Dimensions:

1) for prisms, the depth and internal width of each compartment based on the average of six measurements symmetrically placed along the axis of the compartment shall be the nominal size $\pm$ 0.1 mm. The length of each compartment shall be the nominal size $\pm$ 0.4 mm;

2) for cubes, the depth of the mould and the distance between either pair of opposite internal faces, each based on the average of four symmetrically placed measurements, shall be the nominal size $\pm$ 0.15 mm;

b) Flatness.

The surface of each internal face shall lie between two parallel planes 0.03 mm apart. The joints between the sections of the mould and between the bottom surface of the mould and the top surface of the base plate shall lie between two parallel planes 0.06 mm apart;

c) Squareness.

The surface of each internal face shall lie between two parallel planes 0.5 mm apart which are perpendicular to the bottom surface of the mould and also to the adjacent internal faces;

d) Parallelism.

The top surface of the mould shall lie between two parallel planes 1.0 mm apart, parallel to the bottom surface;

e) Surface texture[2)].

The surface texture of each internal face shall be 3.2 $\mu$m $R_a$.

#### 12.2.4 *Assembly*

When the cleaned mould is assembled ready for use, the joints between the sections of the mould and between the bottom of the mould and the base plate shall be sealed to prevent the escape of water (using, for example, grease). Excess sealant shall be removed from the assembled mould before moulding. The internal faces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the mortar.

#### 12.2.5 *Number of specimens*

Three specimens shall be prepared for testing at each of two ages, 7 days and 28 days being preferred.

NOTE. Because batch variations are likely to be much greater than testing variations, it is preferable for laboratory specimens to be prepared from three separate batches. Similarly, when testing regular supplies of material on a site, more information will be gained by testing one specimen per batch at each age from several batches.

#### 12.2.6 *Preparation of specimens*

The mortar shall be sampled in accordance with clause **4** of this standard. The specimens shall be made as soon as practicable after mixing but not later than 1 h after addition of the water to the mix except in the case of retarded mixes.

Fill the mould to about half height with mortar and compact the layer of mortar by ramming it with the compacting bar in a uniform manner over the mortar with neither segregation nor excessive laitance. The number of strokes of the compacting bar to produce this specified condition will vary according to the consistence of the mortar but in no case shall fewer than 25 strokes be given. Overfill the mould with more mortar and compact this layer as before. Strike off the surface plane and level with the top of the mould using the palette knife.

Place the mould in a plastic bag, and seal and store at a temperature of (20 $\pm$ 2) $^\circ$C for 1 day to 3 days depending on the early strength of the mortar. The specimens shall then be demoulded without damage, marked for later identification and immediately transferred to the appropriate conditions for subsequent curing. The age at demoulding shall be reported.

#### 12.2.7 *Curing*

##### 12.2.7.1 *Hydraulic curing*

Immerse the specimens in lime-saturated water at a temperature of (20 $\pm$ 1) $^\circ$C and keep them there until 2 min before testing, except that distilled water alone shall be used instead of lime-saturated water if high alumina cement has been used in the mix. The specimens shall be supported so as to allow the water free access to all parts of each face.

Fill the containers in which the specimens are to be cured to a sufficient depth to submerge the specimens and maintain at this level by topping up as required.

Not less frequently than every month, empty the container and clean out and renew the water. In no instance shall specimens made from mortars of different types be immersed in the same water either together or at different times.

NOTE. Specimens made from mortars of different designations of the same type, however, may be immersed together.

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[2)] This is understood to mean that a surface with any $R_a$ value from zero to the stated value is acceptable.

**12.2.7.2** *Moist air curing*

The specimens shall be stored over water in a closed airtight container having a volume not greater than 0.015 $m^3$ at a temperature of (20 ± 2) °C.

Specimens made with cement shall be immersed in water at (20 ± 1) °C for 4 h to 6 h immediately before testing. Specimens made with gypsum shall be dried for 3 days in a well ventilated oven, maintained at a temperature between 30 °C and 40 °C.

### 12.3 Determination of flexural strength

#### 12.3.1 *Apparatus*

**12.3.1.1** *Testing machine*, of suitable[3] capacity and sensitivity for the test and capable of applying load at the rate specified in **12.3.2**. The machine shall conform to the requirements for Type 2.0 as specified in Part 1 of BS 1610 for repeatability and accuracy. It shall be equipped with a pair of steel rollers to support the specimen and a third steel roller to apply the load. All three rollers shall have a nominal diameter of 10 mm and shall be at least as long as the width of the specimen and shall be positioned so that their axes are normal to the specimen under test. The distance between the axes of the supporting roller shall be (75.0 ± 1.0) mm from 100 mm prisms and (100 ± 1.0) mm for 160 mm prisms.

The loading roller shall be located midway between the support rollers and shall be free to rotate in the vertical plane through its axis. The parallelism tolerance for the horizontal axis of one support roller with respect to the horizontal axis of the second support roller as datum shall be 0.04 mm wide.

NOTE. This may be achieved by allowing one of the support rollers to be free to rotate in the vertical plane through its vertical axis.

#### 12.3.2 *Procedure*

The specimen[4] shall be tested immediately on being removed from the water and while it is still in a wet condition. Wipe the bearing surfaces of the rollers and the sides of specimen with a clean cloth to remove any loose grit or other material. Place the specimen with one side as cast on the supporting rollers without packing between them. Apply the load without shock at a uniform rate in the range 0.02 N/($mm^2$·s) to 0.1 N/($mm^2$·s) until failure occurs.

NOTE. A loading rate at the lower end of the permitted range may need to be used for the weaker mortars.

The maximum load applied, in newtons, during the test shall be recorded. The broken specimen shall be returned to the water and kept there until required for compressive strength measurement.

Calculate the modulus of rupture, $m$, in newtons per square millimetre as follows:

$$m = \frac{3}{2} \cdot \frac{Pl}{bd^2}$$

where

$P$ is the maximum load applied to the prism, in newtons;

$l$ is the distance between the axes of the support rollers, in millimetres;

$b$ is the width of prism at the line of fracture, in millimetres;

$d$ is the depth of prism at the line of fracture, in millimetres.

Report the modulus of rupture to the nearest 0.01 N/$mm^2$ for individual specimens and to the nearest 0.05 N/$mm^2$ for the mean of three tests.

### 12.4 Determination of compressive strength

#### 12.4.1 *Apparatus*

**12.4.1.1** *Testing machine for prisms*, of suitable[5] capacity and sensitivity for the test and capable of applying load at the rate specified in **12.4.2.1**. The machine shall conform to the requirements for Type 2.0 as specified in Part 1 of BS 1610 for repeatability and accuracy. The upper machine platen shall be able to align freely as contact is made with the specimen but the platens shall be restrained (by friction or other means) from tilting with respect to each other during loading.

**12.4.1.2** *Pair of bearing plates for prisms*, made of tungsten carbide or, as a second preference, of steel of surface hardness at least 53 Rockwell (scale C) hardness value as described in BS EN 10109. The plates shall be 45.0 mm long × (25.0 ± 0.1) mm wide × 8.0 mm thick for testing 25 mm prism sections, and 60.0 mm long × (40.0 ± 0.1) mm wide × 10.0 mm thick for testing 40 mm prism sections. The dimensional tolerance for the width shall be based on the average of four symmetrically placed measurements. The flatness tolerance for the contact faces shall be 0.01 mm.

NOTE. If the machine is fitted with platens (25 ± 0.1) mm or (40 ± 0.1) mm square respectively, the bearing plates are not necessary.

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[3] The capacity of a testing machine is suitable when the expected load at failure of the specimen lies in the upper four-fifths of the range of the machine being used.

[4] Gypsum-based specimens are tested dry (see **12.2.7.2**).

[5] The capacity of a testing machine is suitable when the expected load at failure of the specimen lies in the upper four-fifths of the range of the machine being used.

**12.4.1.3** *Compression jig for prisms*, which may be used to facilitate the location of the bearing plates. The base plate of the jig shall be of hardened and tempered tool steel and the faces shall have a flatness tolerance 0.01 mm wide assessed in accordance with the principles of BS 308 : Part 3. A device to provide positive centring on the lower platen of the testing machine shall be provided. The hardened and tempered silver steel pillars shall be symmetrically placed about the centring device so that the gap in one direction is the nominal width of the prism + 0.3 mm and in the other direction is the normal width of the prism + 0.8 mm. The top face of the base plate shall be marked with an arrow in the direction of the greater distance between the pillars to indicate the direction of the long axis of the bearing plates. A jig suitable for use with 25 mm prisms is shown in figure 6.

**12.4.1.3.1** *Testing machine for cubes*, of suitable capacity and sensitivity for the test and capable of applying the load within the range specified in **12.4.2.2**. It shall conform as regards repeatability and accuracy to the requirements of Part 1 of BS 1610.

The testing machine shall be equipped with two rigid bearing platens made of a material that will not deform irreversibly or wear excessively in normal use. In order to avoid excessive wear, it is recommended that the surface hardness should have a Vickers hardness value (HV) of at least 550 HV (see BS 427). 'Normal use' implies the testing of mortar specimens and the use of proving devices in accordance with Part 1 of BS 1610. The platens shall be at least as large as the nominal size of the specimen to which the load is applied.

The upper machine platen shall be able to align freely as contact is made with the specimen, but the platens shall be restrained (by friction or other means) from tilting with respect to each other during loading.

The flatness tolerance (see BS 308 : Part 3) for the area to be in contact with the specimen shall be 0.03 mm wide and the surface texture (see BS 1134) shall be 3.2 μm $R_a$. This shall be taken to mean that a surface with any $R_a$ value from zero to the stated value is acceptable.

**12.4.2 *Procedure***

**12.4.2.1** *Prisms*

Wipe clean the bearing surfaces of the testing machine, bearing plates and jig. The specimen[6)], which shall be tested immediately on being removed from the water in which it has been stored and whilst it is still in a wet condition, shall be wiped clean of any loose grit or other material, particular attention being paid to the sides of the specimen as cast. Place the specimen in the machine so that the load can be applied to opposite faces as cast, with the cast end of the prism 16 mm from the nearer edges of the platens or bearing plates. If the fracture resulting from the flexural test is such that there is not a cube of solid material between the top and bottom platens or bearing plates, discard the specimen. Carefully align the specimen so that the load is being applied to the whole width of the faces in contact with the platens. When using the bearing plates and jig, place one bearing plate on the upper surface of the jig with its long axis parallel to the indicating arrow ensuring that it makes close contact over the whole surface. Place the specimen in the jig, between the pillars, with its long axis perpendicular to the arrow and place the other bearing plate on top of the specimen parallel to the lower bearing plate. Carefully centre the compression jig assembly on the lower platen of the testing machine.

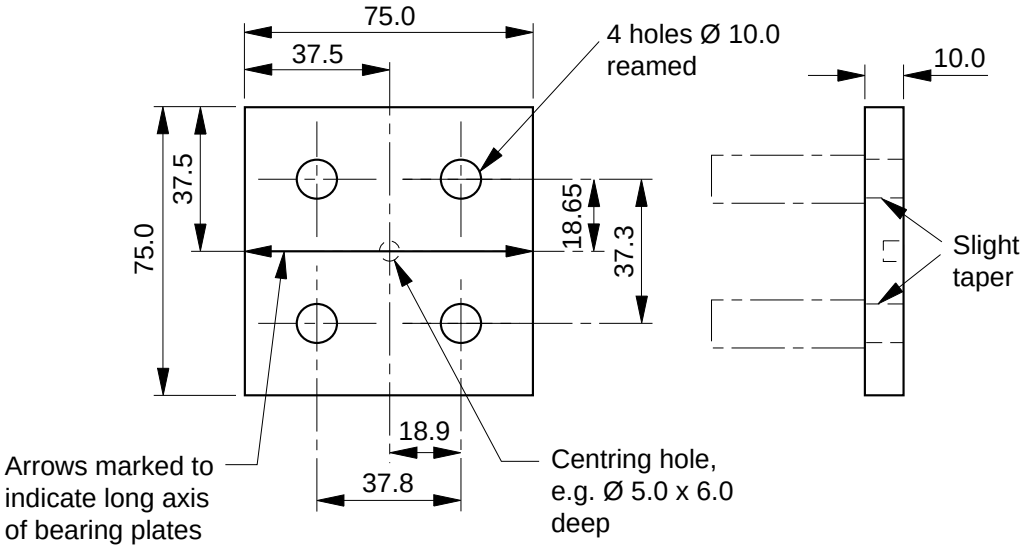
The load shall be applied without shock and increased continuously at a rate within the range 0.03 N/(mm$^2$·s) to 0.1 N/(mm$^2$·s) until failure occurs.

NOTE. A loading rate at the lower end of the permitted range may need to be used for the weaker mortars.

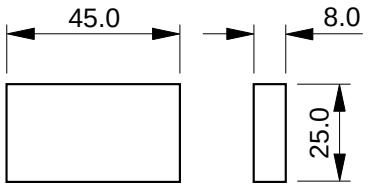
The compressive strength shall be calculated as the maximum load carried by the specimen divided by the cross-sectional area of the specimen in contact with the platen or bearing plate.

Report the compressive strength to the nearest 0.05 N/mm$^2$ for individual results and to the nearest 0.1 N/mm$^2$ for the mean of six tests.

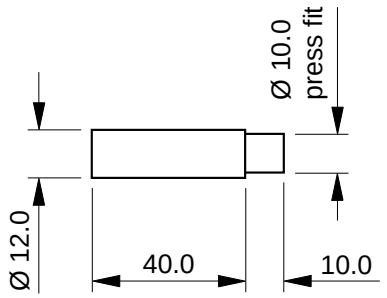
6) Gypum-based specimens are tested dry (see **12.2.7.2**).




Hardened and tempered tool steel base plate




Hardened and tempered tool steel bearing plates




Hardened and tempered silver steel pillars

All dimensions are in millimetres.

**Figure 6. Compression jig for 25 mm × 25 mm × 100 mm mortar specimens**

**12.4.2.2** *Cubes*

Test the specimen[7)] immediately on removing from the curing water in which it has been stored and while it is still in a wet condition. Remove any loose grit or other material from the sides of the cube as cast. Wipe the bearing surfaces of the testing machine with a clean cloth and place the specimen in the machine in such a manner that the load is applied to opposite sides of the cube as cast, i.e. not to the top and bottom. Carefully centre the cube on the lower machine platen. No packing other than auxiliary steel platens shall be used between the faces of the specimen and the steel platen of the testing machine. Auxiliary platens shall conform to the requirements of clause **6** of BS 1881 : Part 115 : 1983.

Apply the load on the specimen without shock and at a uniform rate within the range 0.03 N/(mm$^2$·s) to 0.1 N/(mm$^2$·s) until failure occurs.

NOTE. A loading rate at the lower end of the permitted range may need to be used for the weaker mortars.

The compressive strength shall be calculated as the maximum load carried by the cube divided by the cross-sectional area.

Report the compressive strength to the nearest 0.05 N/mm$^2$ for individual results and to the nearest 0.1 N/mm$^2$ for the mean of three tests.

## 13 Determination of bulk density of hardened mortar

### 13.1 Principle

This clause specifies the procedure to be used for determining the bulk density of hardened mortar specimens by the water displacement method.

### 13.2 Apparatus

**13.2.1** *Analytical balance*, sensitive to 1 mg, fitted with a stirrup of thin, but adequately stiff, wire to hold the specimen and a bridge over the balance pan to support a beaker containing the immersion liquid, or a balance fitted with an attachment for weighing samples suspended below the balance pan.

### 13.3 Procedure

Select a single undamaged piece of hardened mortar of suitable size from the sample and immerse in distilled water for 24 h. Suspend the sample from the balance arm by means of the wire stirrup and weigh while completely submerged in the water, at temperature, $T$, contained in a beaker supported on the bridge over the balance pan ($M_1$).

Ensure that neither the specimen nor the stirrup touches the sides of the beaker during the weighing operation. The mass of the wire stirrup alone, when submerged to the same depth of immersed stem, shall be determined ($M_2$). The corrected mass in grams of the specimen alone in water shall be calculated as ($M_1 - M_2$).

NOTE. With automatic balances weighing by deflection, the apparent mass of the wire stirrup in water should be determined for two lengths of immersed stem and the correction $M_1$ found by interpolation.

Remove the specimen from the water and rapidly dry its surface by gently dabbing it with absorbent cloth or paper and then weigh in air ($M_3$).

NOTE. To prevent errors caused by evaporation of absorbed water while weighing, the surface-dry specimen may be enclosed in a preweighed container before weighing.

The specimen shall then be dried to constant mass ($M_4$) at (105 ± 5) °C.

### 13.4 Calculation

The dry bulk density of the specimen shall be calculated from the above weighings and is equal to:

$$\frac{\rho M_4}{M_3 - (M_1 M_2)} \times 1000 \text{ kg/m}^3$$

The saturated bulk density of the mortar specimen is equal to:

$$\frac{\rho M_3}{M_3 - (M_1 - M_2)} \times 1000 \text{ kg/m}^3$$

where

$\rho$ is the relative density of water at temperature $T$.

[7)] Gypsum-based specimens are tested dry (see **12.2.7.2**).

## 14 Certificate of physical tests

The certificate of physical tests on laboratory prepared mortars and mortar submitted to the laboratory in a ready-mixed form shall include the following information:

a) materials and proportions (see **5.2**);

b) mixing procedure for laboratory prepared mortars (see **5.4**);

c) information from the certificate of sampling freshly mixed mortar (see **4.2.5**);

d) mixing procedure for ready-mixed mortar (see **6.3** and **6.4**);

e) consistence by dropping ball, reported to the nearest 0.1 mm (see clause **7**);

f) consistence retentivity, reported to the nearest 5 % and water retentivity reported to the nearest 1 % (see clause **8**);

g) determination of flow, reported to the nearest 5 % (see clause **9**);

h) air content, determined by the density method and reported to the nearest 0.1 % (see **10.2**);

i) air content, determined by the pressure method and reported to the nearest 0.1 % (see **10.3**);

j) stiffening rate determined to the requirements of method **11.2**a) to the nearest 15 min (see **11.4.7**);

k) stiffening rate determined to the requirements of method **11.2**b) to the nearest 0.05 (see **11.4.7**);

l) flexural strength, reported to the nearest 0.01 $N/mm^2$ for individual specimens and to the nearest 0.05 $N/mm^2$ for the mean of the three tests, together with the age of test (see **12.3**);

m) compressive strength, reported to the nearest 0.05 $N/mm^2$ for individual specimens and to the nearest 0.1 $N/mm^2$ for the mean of the three tests, together with the age at test (see **12.4**);

n) bulk density of hardened mortar reported to the nearest 50 $kg/m^3$ (see clause **13**).

# Annex

## Annex A (normative)
## Details of the apparatus used for the determination of flow

### A.1 Flow table

NOTE 1. The flow table (see figure A.1) is based on the American Society for Testing and Materials Tentative Specification C 230-68T [1], with acknowledgements, in which working drawings may be found. The intention is that the table top and mould specified in BS 890, and the ASTM table top and mould specified in this standard, which are different, should be interchangeable in a similar frame by use of the same shaft. Manual operation is permitted in this standard.

The standard flow table consists essentially of a brass or bronze horizontal smooth table top (with a polished surface) ($254 \pm 2.5$) mm in diameter with an edge thickness of 7.6 mm and stiffened by six integral ribs, mounted on a straight vertical shaft (($15.82 \pm 0.03$) mm in diameter), which may be raised and then allowed to fall freely by a cam, the fall being ($12.72 \pm 0.13$) mm for new tables and ($12.72 \pm 0.38$) mm for tables in use.

The boss on the underside of the table top is attached coaxially to the shaft.

Lines are engraved on the upper surface of the table top to a depth of 0.3 mm with a 60° tool, and are filled in with wax polish, flush with the surface of the metal. See figure A.1.

The length of the fall is defined by a hexagonal shoulder, 31.8 mm across the flats, integral with the shaft with a 1 mm deep circle of 31.8 mm diameter, at the top and bottom, contacting the frame of the instrument and the table.

The total mass of the moving part which is free to fall, i.e. the table top and shaft, is ($4.10 \pm 0.05$) kg, and the mass is symmetrical around the centre of the shaft.

The supporting frame (see figure A.1) is integrally cast of fine grained, high-grade cast iron. The frame casting has three integral stiffening ribs extending the full height of the frame and located 120° apart. The top of the frame is chilled to a depth of approximately 6 mm and the face ground and lapped square with the bore to give a 360° contact with the shaft shoulder. The underside of the base of the frame is ground to secure a complete contact with the steel plate beneath.

The cam and vertical shaft are of medium carbon steel, hardened where indicated in figure A.1. The part of the shaft below the shoulder consists of two hardened bearing surfaces each 25.4 mm in length and ($15.82 \pm 0.03$) mm in diameter, separated by a portion where the diameter is reduced to facilitate lubrication. The length of the shaft below the shoulder is approximately 105 mm but adjusted to give the specified drop.

The difference between the diameter of the shaft and the diameter of the bore of the frame, at the bearing areas, shall be not less than 0.05 mm and not more than 0.08 mm for new tables or 0.05 mm to 0.25 mm for tables in use. The end of the shaft does not fall upon the cam at the end of the drop but makes contact with the cam not less than 120° from the point of drop. The face of the cam is a smooth spiralled curve of uniformly increasing radius from 12.7 mm to 31.8 mm in 360° so that there is no appreciable jar as the shaft comes into contact with the cam. The cam location contact faces with the shaft are such that the table does not rotate more than one revolution in 25 drops. The surfaces of the frame and the shoulder that come into contact at the end of the drop are maintained smooth and horizontal and parallel with the table top, and shall make continuous contact over a full 360°.

The flow table is actuated either by means of a handle attached to the cam shaft having an arm of 101.6 mm radius, or through a flexible drive by a motor to drive the shaft at 100 r/min.

The table is mounted by tightly bolting to a cast iron or steel plate at least 25 mm thick and 250 mm square. The top surface of this plate is machined to a smooth plane surface, and is anchored to the top of a concrete pedestal by four 12 mm bolts that pass through it and that are embedded at least 120 mm in the pedestal. The pedestal is cast inverted on the base plate, and a positive contact is obtained between the base plate and the pedestal at all points. No nuts or other levelling devices are used between the plate and pedestal. Levelling is effected by suitable means under the base of the pedestal.

The pedestal is ($265 \pm 15$) mm square at the top and ($395 \pm 15$) mm square at the bottom, ($695 \pm 65$) mm in height and is of monolithic construction, cast in concrete with a minimum density of 2240 kg/m$^3$. A stable cork pad, 12 mm thick and approximately 100 mm square, is inserted under each corner of the pedestal. The flow table shall be checked for levelness of the top, stability of pedestal, and tightness of bolts and nuts in table base and pedestal plate. A torque of 30 N·m shall be used when tightening these fastenings.

NOTE 2. Loose bolts can cause inaccurate results to be obtained.

Ensure that the table top, after the frame has been mounted on its pedestal, is horizontal, in both the raised and lowered positions.

The vertical shaft of the table shall be kept clean and lightly lubricated with SAE 10, or a similar oil. Ensure that no oil is present between the contact faces of the table top and the supporting frame.

NOTE 3. Oil on the cam face will lessen wear and promote smoothness of operation.

NOTE 4. Oil between the contact faces of the table top and supporting frame can cause significant reductions in values of flow.

### A.2 Mould

The mould shall be a truncated conical metal mould having walls not less than 5 mm thick, smooth inside, (50.8 ± 0.5) mm in height with the narrower end (69.9 ± 0.5) mm and the wider end (101.6 ± 0.5) mm internal diameter. The ends of the mould, at right angles to its axis, shall be smooth (see figure A.1).

NOTE 4. The outside of the top edge of the mould may be so shaped as to provide an integral collar for convenient lifting, or the exterior diameter may be uniform, with the wall having a thickness of not less than 5 mm at the wide end.

### A.3 Tamper

The tamper shall be made of an impermeable, durable material, such as a rubber compound having a Shore A durometer hardness of (80 ± 10) or seasoned oak wood, made non-absorptive by immersion for 15 min in paraffin wax at approximately 200 °C. It shall have a cross section of 12 mm by 25 mm and a length of 125 mm to 150 mm. The tamping face shall be flat and at right angles to the length of the tamper.

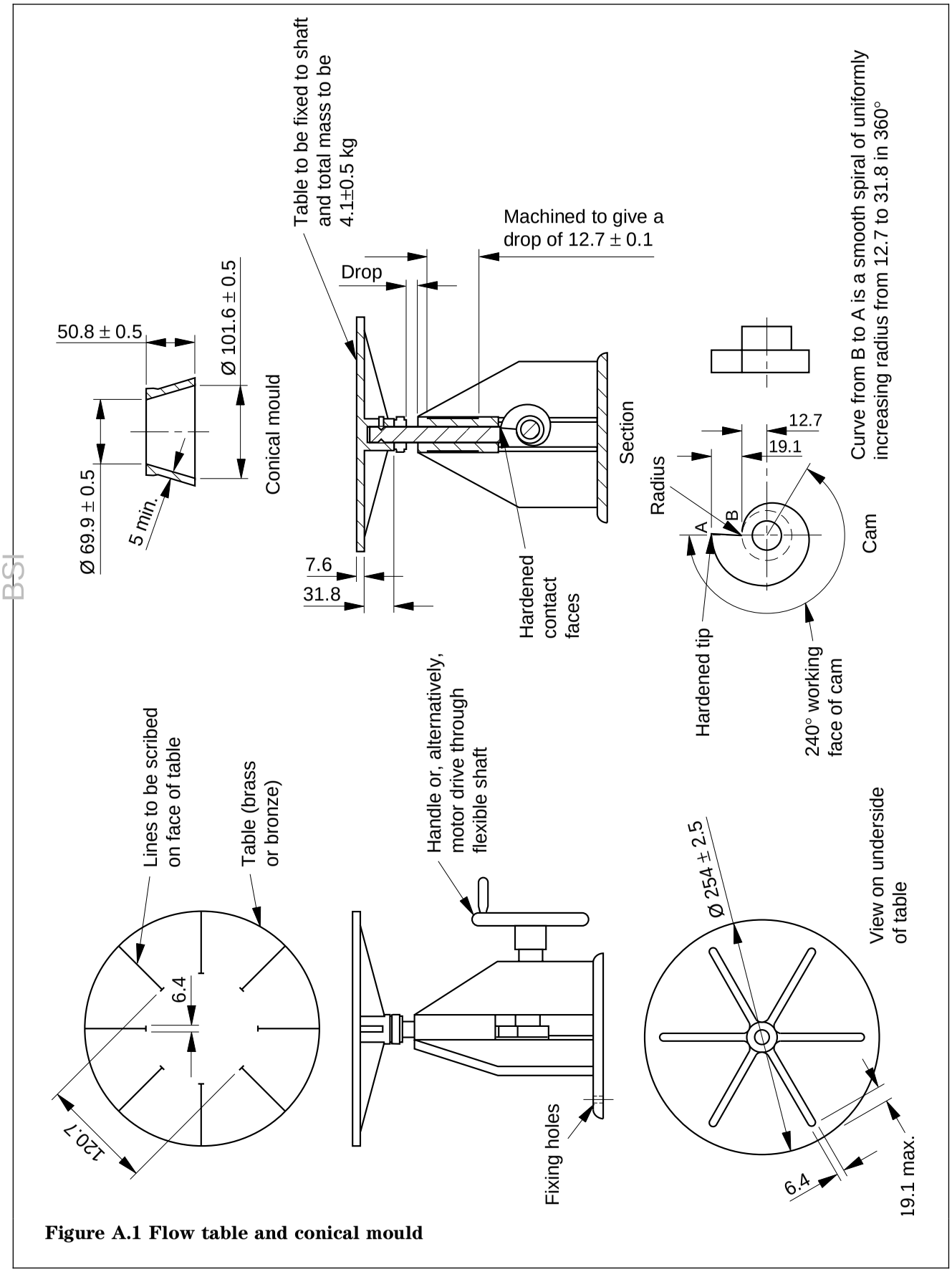



**Figure A.1 Flow table and conical mould**

# List of references (see clause 2)

## Normative references

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| | |
|---|---|
| BS 12 : 1996 | *Specification for Portland cement* |
| BS 308 : | *Engineering drawing practice* |
| BS 308 : Part 3 : 1990 | *Recommendations for geometrical tolerancing* |
| BS 812 | *Testing aggregates* |
| BS 890 | *Specification for building limes* |
| BS 1134 : | *Assessment of surface texture* |
| BS 1134 : Part 1 : 1988 | *Methods and instrumentation* |
| BS 1191 : | *Specification for gypsum building plasters* |
| BS 1191 : Part 1 : 1973 | *Excluding premixed lightweight plasters* |
| BS 1191 : Part 2 : 1973 | *Premixed lightweight plasters* |
| BS 1610 | *Materials testing machines and force verification equipment* |
| BS 1610 : Part 1 : 1992 | *Specification for the grading of forces applied by materials testing machines when used in the compression mode* |
| BS 1881 : | *Testing concrete* |
| BS 1881 : Part 115 : 1983 | *Specification for compression testing machines for concrete* |
| BS 4027 : 1996 | *Specification for sulfate-resisting Portland cement* |
| BS 4550 : | *Methods of testing cement* |
| BS 4550 : Part 5 : 1978 | *Standard sand for concrete cubes* |
| BS 4551 : | *Methods of testing mortars, screeds and plasters* |
| BS 4551 : Part 2 : 1998 | *Chemical analysis and aggregate grading* |
| BS 4887 : | *Mortar admixtures* |
| BS 4887 : Part 1 : 1986 | *Specification for air entraining (plasticizing) admixtures* |
| BS 5224 : 1995 | *Specification for masonry cement* |
| BS 6100 : | *Glossary of building and civil engineering terms* |
| BS 6100 : Part 6 : | *Concrete and plaster* |
| BS 6100 : Part 6 : Section 6.1 : 1984 | *Binders* |
| BS 6100 : Part 6 : Section 6.2 : 1986 | *Concrete* |
| BS 6100 : Part 6 : Section 6.3 : 1984 | *Aggregates* |
| BS 6100 : Part 6 : Section 6.6 : | *Products, applications and operations* |
| BS 6100 : Part 6 : Section 6.6 : Subsection 6.6.2 : 1990 | *Plaster* |
| BS EN 10109 | *Metallic materials — Hardness test* |
| BS EN 10109 : Part 1 : 1996 | *Rockwell test (scales A, B, C, D, E, F, G, H, K) and Rockwell superficial test (scales 15 N, 30 N, 45 N, 15 T, 30 T and 45 T)* |

## Informative references

### BSI publications

BRITISH STANDARDS INSTITUTION, London

| | |
|---|---|
| BS 427 : 1990 | *Method for Vickers hardness test and for verification of Vickers hardness testing machines* |

## Other references

AMERICAN SOCIETY OF TESTING AND MATERIALS
100 Barr Harbor Drive, West Conshohocken, PA 19428
[1] C230-68T Tentative Specification

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